ACCOMPLISHMENT REPORT

PROPULSION DIRECTORATE
January 2000

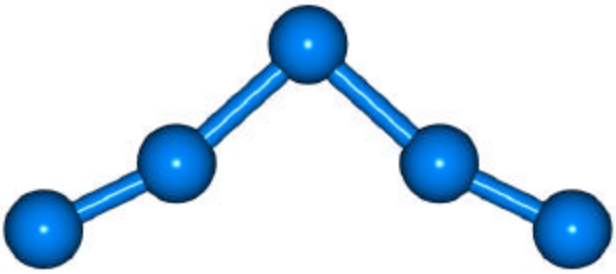
LIU WINS HAROLD BROWN AWARD: Dr. Chi Tsieh ("Jimmy") Liu of the Propulsion Directorate's Propulsion Materials Applications Branch (AFRL/PRSM) is the latest recipient of the prestigious Harold Brown Award. Named for a former Secretary of the Air Force, this Air Force-level award recognizes significant achievement in R&D by one person that led to, or demonstrated the promise of, a substantial improvement in the operational effectiveness of the Air Force. Dr. Liu greatly increased the operational effectiveness of the Air Force's solid rocket motor fleet through his outstanding research in solid propellant fracture mechanics and service-life prediction. Dr. Liu used the techniques he developed to verify the viability of contaminated propellant in several Titan IV motor segments. His efforts saved the Air Force at least $100 million in launch delays and motor remanufacturing costs. Ms. Carol DiBattiste, the Under Secretary of the Air Force, presented the Harold Brown Award to Dr. Liu in a ceremony at the Pentagon on 10 January 2000. (J. Liu, AFRL/PRSM, (661) 275-5642)

Dr. Jimmy Liu (top) and a Titan IV launch (bottom)

IHPTET JETEC DEMO INCORPORTATES NEW LUBRICATION TECHNOLOGY: Personnel from the Propulsion Directorate, the Navy, and Allison Advanced Development Company (AADC) attended the Joint Expendable Turbine Engine Concept (JETEC) Phase II demonstrator fire-up on 30 November 1999. The JETEC demonstrator, designated XTL-16, is a small turbojet intended for both sea skimming target and high altitude supersonic cruise missile applications. It incorporates a number of advanced technologies, some which will be demonstrated for the first time in a full-scale turbojet configuration. The rear support for the engine's rotating group is provided by a unique STROD support system which contains a vapor-phase (VP) lubricated, high temperature hybrid ceramic roller bearing and dry impact damper. This system will be demonstrated for the first time in a turbojet and was developed through the following programs: Lubrication Branch (AFRL/PRSL) in-house program, AFOSR Program, and Integrated High Performance Turbine Engine Technology (IHPTET) Program. The STROD/VP-bearing/impact damper system will help slash 31 percent of engine weight, reduce

cost by 4 percent, and allow hot-section mechanical components to operate at temperatures never before achieved in an operational turbojet. There will be minimal cooling bleed air, a factor critical for meeting IHPTET Phase II specific thrust and cost goals. Engine testing will commence with ambient windmilling for pressure instrumentation and data acquisition check, followed by ambient start-to-idle test for engine vibration and operational checkout, and finally the Phase II specific thrust goal demonstration. (L. Rosado, AFRL/PRSL, (937) 255-6519)

PR BREAKTHROUGH MAKES AMERICAN CHEMICAL SOCIETY'S TOP 5 FOR '99: The 29 November 1999 issue of *Chemical & Engineering News*, a weekly publication of the American Chemical Society (ACS), lists "Synthesis of a N_5^+ salt" as one of the top five achievements in chemistry for 1999. This AFRL achievement was selected because it is the "…essence of what chemists do…: Chemists make interesting new stuff." N_5^+ was discovered as a cation in the molecule N_5AsF_6 by Drs. Karl O. Christe and William W. Wilson, on-site contractors with the Propulsion Directorate's Propellants Branch (AFRL/PRSP). Christe and Wilson made this discovery as participants of the High Energy Density Matter (HEDM) team, a group devoted to finding and producing new high-powered rocket propellants or additives that exceed current capabilities for use in future Air Force systems. Though specific applications for this substance are yet to be identified, it is believed that N_5^+ can be combined with an energetic anion to yield a highly energetic propellant or explosive ingredient. (J. Boatz, AFRL/PRSP, (661) 275-5364)

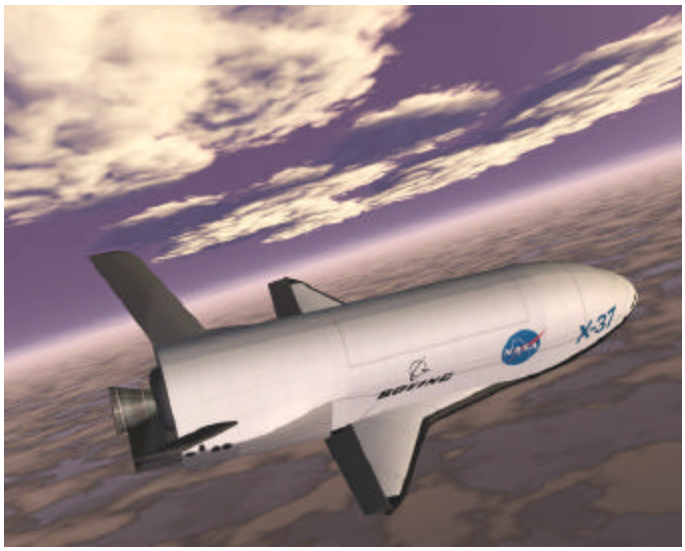


Drs. Karl O. Christe and William W. Wilson (top) and the N_5^+ cation (bottom)

NOVEL PLASMA THRUSTER BEING DEVELOPED: Personnel in the Propulsion Directorate's Rocket Propulsion Division (AFRL/PRR) are enjoying success in their explorations of a propulsion concept known as the Pulsed Plasma Thruster (PPT). PPT systems provide thrust by electromagnetic acceleration of propellants using a discharge of energy. This technology is being developed for space applications with an emphasis on exploring novel ways of making the technology more efficient, reliable, and affordable. Recently, testing has focused on determining the optimal configurations of two designs, the Self-Triggered and Quasi-Steady MicroPPTs. Tests are performed by varying the average discharge energy vs propellant surface area and characterizing its effect on the ablation pattern. The effect of the fuel bar material on lifetime is also being examined. During recent testing, the longest test firing to date of the Self-Triggered MicroPPT was achieved with the device firing for 5¼ hours and logging over 18,000 shots. This testing is making significant inroads into understanding the relationship

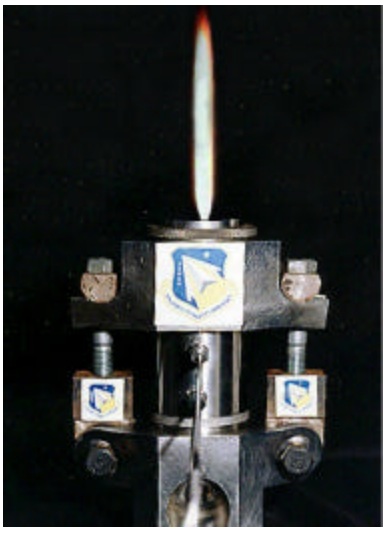
between shot energy and propellant erosion of the Self-Triggered MicroPPT. (L. Quinn, AFRL/PRR, (661) 275-5630)

MAGNETIC FIELD SYSTEMS FOR HYPERSONIC VEHICLES: Personnel from the Propulsion Directorate's Superconductivity Group (AFRL/PRPS) and the Air Vehicles Directorate (AFRL/VAA) have entered discussions with Boeing and the National High Magnetic Field Laboratory (NHMFL) to explore the use of magnetic fields for plasma aerodynamics and hypersonic applications. Analysis of various hypersonic system concepts (e.g., space X-planes and Dual Fuel Mach 7 to 10 (DF-7) vehicles) indicates that the benefits of magnetic field systems are significant. A number of areas have been identified where this technology can be applied for hypersonic systems. These include leading edges for the X-37, large surface area ramp, edge, and combustor magnets for the DF-7, and DF-7 scramjet magnetohydrodynamic (MHD) power concepts. Unfortunately, these benefits are entirely offset by the weight of the magnetic systems, highlighting the need for improved magnetic sources. The NHMFL performs high magnetic field research, assists in national magnetic programs (e.g., MagLev and Electric Navy), develops materials, and provides free-of-charge test facilities for industry. To capitalize on the expertise available at the NHMFL, a joint relationship is being established to perform plasma aerodynamics magnet research. (P. Barnes, AFRL/PRPS, (937) 255-2923)



Artist's rendering of the X-37

"GREEN MISSILE" PROPELLANT FIRED FOR FIRST TIME: The Propulsion Directorate's Propellants Branch (AFRL/PRSP) recently fired the first rocket motors they developed under the SERDP (Strategic Environmental Research & Development Program) funded Green Missile Program. The Green Missile Program is a joint program between the Air Force, Army, Navy, NASA, the Environmental Protection Agency (EPA), and the Department of Energy (DoE). In this program, researchers are investigating pollution prevention alternatives in three areas: elimination of lead in minimum signature missile systems, elimination of HCl as a combustion product in smoky systems, and elimination of chlorinated/toxic solvents used in processing propellant oxidizers. The PRSP team aims to produce an environmentally enhanced, solid booster propellant incorporating ultrafine metal fuel. In recent testing, a set of 2×4 motors using a solid propellant comprised of a combination of ultrafine aluminum (UFAL) and magnesium/aluminum alloy was successfully test-fired at the 1-30 Area at Edwards AFB, California. A 2×4 motor is a rocket motor with a 2" diameter chamber and a 4" length used for propellant testing. These subscale



A 2x4 motor firing

motors are used because they give a good approximation of a propellant's ballistic properties and provide a sound basis from which to scale up to larger motors. Data from these recent tests are currently being reduced with a focus on determining the effect of the new fuel on booster propellant ballistics. (A. Brand, AFRL/PRSP, (661) 275-5787)

COLD FUEL RESEARCH EFFORTS MOVING FORWARD: The Propulsion Directorate's Fuels Branch (AFRL/PRSF) is making headway in investigations to improve the low temperature utility of JP-8. The goal of this effort is to develop an additive that will allow JP-8 to be an effective fuel for high altitude Air Force missions. Motivation for this effort originally stemmed from a desire to replace JPTS, the fuel used for the U-2 reconnaissance plane, with the more economical JP-8 since JP-8 is currently about one-fifth the cost of JPTS ($0.62/gallon vs $3.25/gallon). Recently, representatives of PRSF and the University of Dayton Research Institute (UDRI) briefed the Cold Flow Enhancer Program to Lockheed U-2 maintainers at Palmdale, California. The group discussed the U-2 fuel system and UDRI and PRSF personnel had the opportunity to examine the wing tanks of a U-2 that was in for maintenance. This interaction provided information vital to the design of an experimental fuel system simulator to examine fuel behavior in the U-2. Following this encounter, PRSF and UDRI personnel met with Ryan Teledyne fuel system design, airframe, and environmental control engineers to discuss fuel issues related to the Global Hawk unmanned aerial vehicle (UAV). The Global Hawk needs a low-temperature fuel to accomplish its high-altitude (~65,000 feet), long duration photo reconnaissance mission. The interaction with U-2 and Global Hawk experts is focusing the cold fuel program efforts for the near future. (C. Obringer, AFRL/PRSF, (937) 255-6390 and 1Lt K. Wohlwend, AFRL/PRSF, (937) 255-3190)

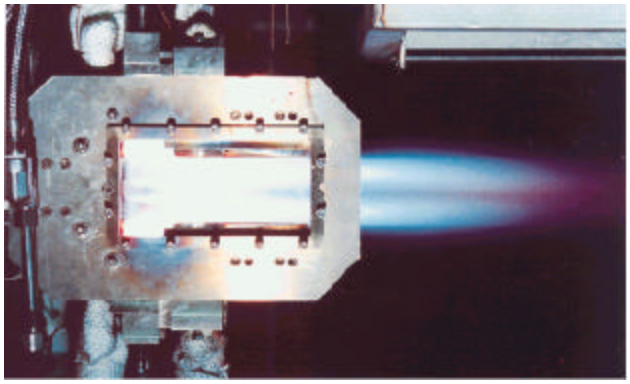
The U-2 (top) and the Global Hawk UAV (bottom)

POTENTIAL APPLICATIONS FOR POSS IN THE F-22: Representatives of the Propulsion Directorate's Propulsion Materials Applications Branch (AFRL/PRSM) recently met with the F-22 System Program Office (SPO) at Wright-Patterson AFB to discuss potential applications for POSS (Polyhedral Oligomeric Silsesquioxanes) polymers. POSS additives radically upgrade the thermal and physical properties of most plastics, and because of its chemical nature, POSS technology is easily incorporated into common plastics via copolymerization or blending. This allows POSS additions to be made with little or no alteration to existing manufacturing processes. The F-22 SPO is interested in POSS for plastic jet canopies, and they also have an interest in a recent Dual Use Science & Technology (DUS&T) award that is focused on developing nanofoamed POSS polymers for canopies and radomes. The F-22 SPO expressed great interest in PRSM's POSS research, and further connections were established with the NGT (Next Generation Transparency) Program and two radome programs where delamination is a major issue. POSS technology is currently at the state where R&D needs to be tied to Air Force applications and parts, and connectivity with the SPOs is a positive step toward this goal. (S. Phillips, AFRL/PRSM, (661) 275-5416)

The F-22

AFRL/NASA TEAM INVESTIGATING FLYWHEEL MOTOR/GENERATORS: Recent satellite mission trade studies conducted by NASA Glenn Research Center have shown that significant mass savings can be realized in a flywheel-based energy storage system by using a generator which provides constant output voltage as the rotational speed of the flywheel drops. This is because the power conditioning electronics needed to provide regulated DC output become much smaller with constant voltage input. A six-month study effort, co-funded by NASA Glenn Research Center and the Propulsion Directorate's Power Division (AFRL/PRP), is investigating conceptual designs of such a machine. The selected contractor, Unison Industries, will design, build, and test a 350 W prototype of their patented concept. Unison's concept uses a stationary low power coil combined with a permanent magnet rotor to provide controlled field excitation that results in an output which is constant with rotor speed. Analyses will investigate scalability of the concept to 75 kW. (C. Kessler, AFRL/PRPG, (937) 255-6241)

JOINT DoE/AIR FORCE COMBUSTOR TESTING INITIATED: Engineers from the Propulsion Directorate's Combustion and High Speed Systems Branch (AFRL/PRSC) are collaborating with the Department of Energy Federal Energy Technology Center



(DoE/FETC) to explore emission reducing combustor technology. The team has conducted exploratory combustion experiments to evaluate the Trapped Vortex Combustor (TVC) stabilization technique in a rich-burn quick-quench lean-burn (RQL) mode of operation. This RQL concept is an effective method of reducing nitric oxide (NO_x) emissions in land-based gas turbine combustors. Data already obtained in testing and data yet to be collected will be used to evaluate whether the TVC concept can be readily applied to land-based gas turbine engines as an RQL combustor. This interaction is part of an ongoing partnership with DoE/FETC to share common technologies, learn from the expertise of the other organization, and promote the synergistic development of innovative gas turbine engine combustor technologies. (R. Hancock, AFRL/PRSC, (937) 255-7487 and Capt I. Vihinen, AFRL/PRSC, (937) 255-8623)

MICROPROPULSION DEVICE PASSES SURVIVABILITY TESTS: The Propulsion Directorate's Aerophysics Branch (AFRL/PRSA) in conjunction with the MicroDevices Lab at NASA's Jet Propulsion Laboratory (JPL) is fabricating a novel micropropulsion system. This system, called the Free Molecule Micro-Resistojet (FMMR), addresses the need for low mass, low power, efficient, simple, and robust thrusters to provide thrust for microsatellites. The FMMR was developed by researchers at AFRL/PRSA. The Mark I.2 version of the FMMR, fabricated at JPL, was recently tested at the University of Southern California (USC). The Mark I.2 version of the FMMR utilizes a silicon nitride layer and features a wider heater (200 µm wide) which has been able to survive the current flow. To date, performance of the Mark I.2 FMMR chips has been excellent. These chips have survived temperatures up to 650K (710°F) without degradation, and one Mark I.2 chip was held at 600K (620°F) for over 500 minutes and continued to run. Overall, the Mark I.2 chip has exceeded 3,000 minutes of operation without significant degradation or signs of failure, and the survivability goal for the Mark I chip has been surpassed. The next step is to perform heat transfer measurements on the chips under vacuum. The vacuum system has been completed and is ready to accept FMMR chips as soon as they can be provided. Further lifetime and cycling tests will continue with this and other chips, and current plans are to fly the FMMR on a microspacecraft from Arizona State University in late 2001. (A. Ketsdever, AFRL/PRSA, (661) 275-6242)

A Free Molecule Micro-Resistojet chip

NOVEL MID-INFRARED SOURCE READY FOR DELIVERY: The Propulsion Directorate's Combustion and High Speed Systems Branch (AFRL/PRSC) is involved in a joint project with the Sensors Directorate's Electro-Optical Targeting Branch (AFRL/SNJT) to promote the development of all-solid-state laser sources for operation in the mid-infrared spectral regime. Such devices will open up new opportunities for species-concentration measurements, engine diagnosis, and sensing with applications to active combustion control, engine-health monitoring, and condition-based maintenance. This unique cross-directorate interaction involves SNJT as the funding organization and program monitor for a Phase II SBIR effort with Aculight Corp, a Seattle-based company specializing in advanced laser technology. PRSC is involved as the recipient for all deliverable hardware produced through the program. The hardware will be evaluated for its combustion diagnostics potential by PRSC scientists and engineers whose feedback will influence future SNJT and Aculight developments. In support of this activity, PRSC and Innovative Scientific Solutions, Inc (ISSI) personnel recently traveled to Aculight where they were trained in the operation of Aculight's mid-infrared source. They also worked with Aculight personnel to define the configuration of the deliverable hardware. (J. Gord, AFRL/PRSC, (937) 255-7431)

PORTABLE WEAR DEBRIS DETECTOR BEING DEVELOPED: The Propulsion Directorate's Lubrication Branch (AFRL/PRSL) is supporting a new Program Reliability and Maintainability (PRAM) funded effort to develop a field-portable filter wear debris analysis unit. This effort is expected to fill the gap in current aircraft wear debris detection capability between on-engine and laboratory techniques. The new unit will merge the latest filter washing, particle counting, and x-ray fluorescence spectrometric technologies. PRSL and the University of Dayton Research Institute (UDRI) will serve the technical oversight and program integrator roles for this effort. In this capacity, they will oversee and assess the technical viability of the technologies as they are integrated into a portable field unit. The Joint Oil Analysis Program – Technical Support Center (JOAP-TSC) will perform laboratory testing on aircraft filter samples, compare their results with those of the prototype field unit, and assist in building a database and software library for debris analysis. GAS-TOPS, a developer of particle counting, filter washing, and engine health monitoring software technologies, will build the field unit and fill the role of developing rugged, easy-to-use hardware and software. XSI, a small x-ray spectrometer development and manufacturing company, will supply a ruggedized, miniaturized x-ray fluorescence spectrometer built to GAS-TOPS' specifications. (R. Wright, AFRL/PRSL, (937) 255-5568)

INTERNATIONAL COOPERATIVE EFFORT LEADS TO NOVEL CATHODE MATERIAL: A new ionic liquid is being developed as part of the Doctoral research performed by David Ryan at Miami University in Oxford, Ohio. This pioneering effort to develop the first cathode-specific ionic liquid is a collaboration between Mr. Ryan of the Propulsion Directorate's Battery Branch (AFRL/PRPB) and Dr. Tom Welton, Department of Chemistry, University of Exeter, UK. This work is an extension of earlier work to expand the electrochemical window of room temperature molten

Cathode-specific ionic liquid for batteries

salts and a survey of highly oxidized vanadium compounds to be used as battery cathode materials. This effort will complement ongoing work in PRPB with room-temperature molten salts used as electrolytes for the new environmentally friendly Lithium-ion batteries. A paper has been prepared for publication in *Inorganic Chemistry*, a publication of the American Chemical Society. (D. Ryan, AFRL/PRPB, (937) 255-7770)